Section 2.0
Technology Applications Analysis

This section addresses the general applicability of the EcoMat Inc. BDN Technology to sites containing groundwater contaminated with nitrate. The analysis is based on results from and observations made during the SITE Program demonstration and from additional information received from EcoMat Inc. SITE demonstration results are presented in Section 4 of this report. The vendor had the opportunity to discuss the applicability, other studies and performance of the technology in **Appendix A**.

2.1 Key Features of the BDN and Post-Treatment Processes

The EcoMat Inc. BDN Technology is designed to quickly and effectively treat nitrate-contaminated groundwater while generating minimal byproducts. This system is appropriate for treating potential drinking water supplies and may also be effective in treating industrial wastewater or leachate from commercial, industrial, and hazardous waste sites. The system may be most suitable for treating water supplies in agricultural regions that are subject to increased nitrate concentrations due to seasonal fertilizer application. The system can also treat inorganic pollutants, other than nitrate, through cultivation of different types of microbes.

The EcoMat Inc. BDN Technology is a fixed-film bioremendiation process using a biocarrier and bacteria appropriate to the contaminant of concern. In the case of the Bendena water well, the contaminant of concern is nitrate. EcoMat's patented mixed reactor retains the biocarrier in the system, thereby minimizing solids carryover. In addition, the fixed film treatment allows rapid and compact treatment of nitrate with minimal byproducts. Overall, the denitrification process is intended to convert nitrates in the groundwater to nitrogen gas. In addition to demonstrating EcoMat's BDN Technology, the project also included demonstration of a post-treatment system designed to destroy or remove any intermediate compounds potentially generated during the biological breakdown of the nitrate (e.g., nitrite), and also remove small amounts of bacteria and suspended solids that are not attached to the biocarrier. Treatment of VOCs present in the influent can also be accomplished by the post-treatment system by incorporating traditional treatment methods, such as ozonation and air stripping.

The denitrification process is accomplished in two reactors. Reactor 1 (R1), referred to as the "De-oxygenating Tank," includes bioballs loaded with denitrifying bacteria. These bacteria are fed a 50 percent aqueous methanol solution to act as a carbon source for the metabolic processes that remove free oxygen and to act as a carbon source for cell growth. The second reactor (R2), which receives the de-oxygenated water from Reactor 1, is packed with 1-cubic centimeter (cm^3) cubes of a synthetic sponge-like polyurethane biocarrier called "EcoLink." The Ecolink medium hosts the colonies of bacteria cultured for degrading nitrate. An important feature to this medium is that small contiguous holes are incorporated into the medium to maximize surface area for the active bacteria colony and to permit the exit of the nitrogen gas formed during the denitrification process.

Reactor 2 also includes a specially designed mixing apparatus to direct the incoming de-oxygenated water into a circular motion, thus keeping the media in constant circulation and maximizing contact between the water and media. Methanol is also fed to this reactor to encourage nitrate consumption and to act as a carbon source for the anaerobic bacteria degrading the nitrate to nitrogen gas. The effluent from R2 received additional treatment, referred to here as post-treatment. During the course of the demonstration, four different combinations of post-treatment were incorporated into the overall treatment system. Each of the four systems utilized during the demonstration incorporated one or more oxidation components, such as chlorination, ultraviolet (UV) light, or ozonation. In addition to destroying any active bacteria exiting the BDN system, the oxidation component was designed to oxidize: 1) residual nitrite back to nitrate 2) residual methanol, and 3) VOCs in the water (e.g., CCl_4).

During the majority of the demonstration, the post-treatment system also incorporated a filtration component designed to remove suspended solids generated from the BDN process. In addition to using a clarifying tank, a variety of filter combinations were used, including a sand filter, a carbon filter, and different sized cartridge filters (i.e., rough, high efficiency, and polishing filters).

The developer believes that the denitrification technology is capable of effectively converting nitrate and methanol to nitrogen gas and carbon dioxide. This aspect was of primary interest for this demonstration. The developer also claims that the post-treatment or polishing step can 1) oxidize any residual nitrite to nitrate, 2) oxidize residual methanol, 3) destroy bacterial matter exiting the EcoMat reactor, and 4) remove suspended solids. No claim was made concerning the removal of VOC's.

2.2 Operability of the Technology

The prime factor in determining the effectiveness of the EcoMat Inc. BDN Technology is the growth of a healthy population of naturally-occurring anoxic bacteria (denitrifiers) to reduce nitrate to nitrogen gas and carbon dioxide in the presence of methanol. The growth of these denitrifiers is dependant upon a number of factors including nitrate-N concentration, pH, temperature, and carbon concentration. In addition, continuous operation with minimal process disruptions, including shutdowns, is critical to maintaining a healthy microbial population. Overall, the EcoMat technology is designed to provide optimum conditions for growing and sustaining an active bacteria colony.

The EcoMat technology is an ex situ process consisting of a BDN and a post-treatment system. The BDN system includes two reactors in series, followed by an overflow tank. Each reactor is two cubic meters in size with a water capacity of approximately 1,100 gallons. The first reactor (R1), referred to as the "Deoxygenating Tank" is equipped with ports for both the tank's influent and effluent, and a methanol feed. The second reactor (R2), referred to as the "EcoMat Reactor," is also equipped with ports for the influent, effluent. and methanol feed. The final component of the BDN system is a small overflow tank capable of holding approximately 200 gallons.

Prior to system start-up, a shakedown period is required to begin BDN by developing the necessary biological growth on the "biocarrier" in the bioreactor chamber under full recycle. The shakedown period normally takes approximately six weeks. This 6-week period gives the system operators an opportunity to adjust water flow and methanol feed rates based on observed nitrate and nitrite concentrations and other factors.

Since each of the reactors maintains large populations of sensitive microbes, continuous operation of the system is critical. The growth of denitrifying bacteria on the biocarrier in the Deoxygenating Tank is dependent upon achieving both a relatively low dissolved oxygen concentration (e.g., ~1 mg/l) and an environment rich in carbon. As a result, methanol is routinely fed to the De-oxygenating Tank to act as the source of carbon. To ensure that a healthy population of denitrifiers is maintained, routine monitoring of the methanol concentration is performed.

The Deoxygenating Tank requires little attention and maintenance. The groundwater simply enters the top of the reactor, flows through the bioballs and exits the bottom of the reactor. Level switches near the top of the tank control flow into the tank; these do require routine service.

Continuous operation of the EcoMat Reactor is also critical. Specialized bacteria for degrading nitrate are cultured in this reactor. Since an anaerobic environment is necessary to accomplish denitrification, dissolved oxygen levels are routinely monitored to ensure a concentration of less than 1.0 mg/l.

The EcoMat Reactor is equipped with a patented mixer that is designed to circulate the water within the reactor without the aid of moving parts. This reactor contains EcoLink media which also are circulated by the mixing apparatus. Like the de-oxygenating tank, the EcoMat Reactor also requires minimal operational attention and maintenance. The most common maintenance activity would be periodic replacement of the EcoLink biocarrier, which occasionally becomes overloaded and falls out of suspension.

Specific to the demonstration, delivery of the groundwater to the treatment system was accomplished by a submersible pump installed within PWS Well #1. The submersible pump was originally controlled by a float switch in Reactor #1. To prevent potential burn-out of the submersible pump, the float switch was replaced first with a pressure switch and finally with a "flapper." The line delivering the groundwater to the treatment system was equipped with a totalizer to monitor flow rate. Totalizers were also installed at the treatment system discharge point and on the recycle line for the SITE evaluation.

The post-treatment system included different treatment components during each of the four demonstration events. The four post-treatment scenarios are presented below.

Event 1 -	Chlorination
Event 2 -	Clarification, Sand & Rough (20μm) Filtration, and UV Oxidation
Event 3 -	Ozone, UV Oxidation, Clarification, Rough (20μm) & High Efficiency

	(5μm) Filtration, Carbon Adsorption, & Polishing (1μm) Filtration
Event 4 -	Chlorination, Clarification, High Efficiency (5μm filter) Filtration, Air Stripping, and Polishing (20μm) Filtration

Each component used in the post-treatment system was purchased “off the shelf” from equipment suppliers. Operation of the equipment was learned in the field during the demonstration period and appropriate adjustments to feed and flow rates were made to maximize the effectiveness of treatment. General maintenance of the post-treatment system during the demonstration included flushing out the entire post-treatment system, back washing of the sand filter, drainage of the clarifier, and replacement of the cartridge filters.

Both the BDN and post-treatment systems were installed inside a storage building that was twelve feet wide, twenty feet long, and twelve feet high. The shed was equipped with 1) electricity to operate pumps and provide heat, 2) a potable water supply for cleanup and decontamination activities, and 3) a telephone and facsimile machine hookup. The shed also provided sufficient work space and room for storage of equipment and reagents.

The process, including both the BDN and the post-treatment system, was designed to operate unattended; however, during the four sampling events seven system shutdown periods required the presence of on-site personnel to address the operational problems and bring the system back online. Shutdowns were caused by a combination of mechanical problems and electrical storms causing power outages. Numerous shutdowns during sampling Event 2 resulted in a decision to abort the event and restart when mechanical problems were corrected. It should be noted that additional shakedown periods were required after some of the shutdowns to reestablish microbial populations in the reactors.

2.3 Applicable Wastes

The EcoMat BDN technology is an ex situ fixed- film BDN system designed to destroy or remove nitrates in water. In addition to using the technology on a potential drinking water source during this demonstration, the technology should be applicable to industrial wastewaters and leachate from commercial, industrial, and hazardous waste sites containing elevated nitrate concentrations.

During the demonstration, a post-treatment system designed to remove chlorinated hydrocarbons from water was also evaluated. The developer also claims that the technology is suitable for treating other types of inorganic pollutants since the EcoMat reactor can effectively cultivate microbes that can degrade different contaminants.

An EcoMat biological reactor is currently being used at a Department of Defense facility in Southern California to treat perchlorate. Also, there are EcoMat systems installed at aquariums for removing nitrate from saltwater.

2.4 Availability and Transportability of Equipment

The EcoMat Biological Denitrification and Post-Treatment Process requires a level pad, ideally concrete, and a heated building. The size of the pad and building is dependent on the size of the process installed at a particular site. EcoMat has indicated that it is feasible to install a treatment system outside, which may be necessary for very large systems. In such instances, heat tracing would be installed to provide temperature control.

At the Bendena site, the process consisted of a Deoxygenating Tank, the EcoMat Reactor, an overflow tank, and the post-treatment system (ozone unit, UV treatment, clarifier, sand filter, cartridge filters, air stripper, and carbon filters). This entire process (except for the existing air stripper) and necessary support equipment fit inside a shed that was twelve feet wide, twenty feet long, and twelve feet high. Since this system is designed to be unattended, a trailer or additional office space in the building housing the process should not be necessary.

Equipment and supplies associated with the process were transported to the site by one truck. Each two cubic meter (m^3) reactor tank was delivered to the site in halves to permit for easy handling and assembly. The remainder of the treatment units and associated equipment can be handled and installed by one person.

Depending on well availability at sites intending to use this technology, a drill rig with associated drilling equipment might be necessary. Fortunately, during this demonstration a former railroad well constructed in the early 1900's served as the source for the nitrate-contaminated groundwater. The total well depth is 73.4 feet below ground surface (bgs) and the static water level is approximately 45 bgs; the inside well diameter is approximately 23 feet.

During the demonstration the EcoMat BDN and Post-Treatment systems required periodic maintenance of a number of process units and replacement was necessary for a number of units. Some of the equipment changes necessary during system operation included new pressure switches for controlling tank levels, new PVC piping and hoses to rectify leaks, and new filters to prevent filter microbial buildup. All replacement equipment was either purchased locally or delivered to the site via courier.

Treated water from the system was discharged to a 1,000 gallon septic system specifically purchased and installed for the demonstration. Heavy equipment such as a backhoe may be required for septic system installation.

If the application for septic system installation had been denied due to reasons such as a percolation, slope, depth to groundwater, etc., other discharge options would have been investigated. During this demonstration numerous options were available including discharge to 1) a down slope drainage network, 2) a return line back to the PWS Well #1, or 3) the ground up gradient of PWS Well #1. Ultimately, the intent of this system is to treat the water to meet drinking water standards. Therefore, in an actual installation treated water would be routed directly into the distribution system for delivery to customers in the community. Therefore, the availability and transportability of equipment related to delivery of water into a specific distribution system would need to be investigated.

2.5 Materials Handling Requirements

The major materials handling requirement for the EcoMat BDN and Post-Treatment systems was installation of the individual process units which make-up the treatment system. The KDHE provided a shed and a pumped line from PWS Well #1 to the shed. The shed included all necessary services such as potable water, electricity, heat and a phone line.

The entire system was delivered to the site on one truck. Installation of the system required the support of one person over a period of approximately one week. All process units and associated equipment are small and light enough to permit this one person to unload and install the equipment.

Prior to beginning the demonstration, a variety of activities were necessary to prepare the BDN and Post-Treatment systems for start-up, including a shake down of the equipment. The materials handling requirements for bringing water from the well were minimal since a pumping and groundwater delivery system had already been installed within the PWS well.

The shakedown period simply involved developing the necessary biological growth on the “biocarrier” in the bioreactor chamber. With the exception of more frequent sampling and adjustments to water flow and methanol feed rates, the activities performed during the shakedown period were no different from those that would be performed during routine operation of the system under normal conditions.

If the BDN and Post-Treatment systems are utilized to treat groundwater, installation of one or more wells may be necessary. Drilling services are generally subcontracted to a company which has both the required equipment (drill rigs, augers, samplers) and personnel trained in drilling operations and well construction. If work is to be performed on a hazardous waste site, drilling personnel must have the OSHA-required 40-hour health and safety training. Once the well(s) are drilled each must be equipped with a pump to deliver the groundwater to the treatment system. An equalization tank may be necessary to store the feed water rather than pumping directly to the system. All pumps chosen must be able to perform under a variety of conditions.

Depending on the characteristics of the source water, installation of a pretreatment system may be required. Parameters in the source water that may cause inhibition of the BDN system include pH, dissolved oxygen, temperature, and heavy metals.

The BDN system does not generate any hazardous residuals; however, extremely small quantities of non-hazardous residuals are generated by various units in the post-treatment system. Sludge is generated by the clarifying tank and the cartridge filters periodically become clogged and need to be flushed or replaced. Residuals generated during the demonstration included spent filter cartridges and biocarrier media; these were placed in plastic trash bags and discarded in an on-site dumpster.

2.6 Range of Suitable Site Characteristics

Locations suitable for on-site treatment using the EcoMat Denitrification and Post-Treatment System must be able to provide relatively uninterrupted electrical power and potable water for cleanup activities. Electrical power was required for a control panel equipped with high level alarms and reset buttons, and for operation of several electrically driven pumps throughout the system, including a submersible pump to draw water from the well. Power was also required to provide heat to the shed via an electrical heater. Heat was necessary to maintain a minimum water temperature of 60°F in the treatment system and to protect equipment and personnel during cold temperatures. Overall, the EcoMat Biological Denitrification System requires a 115-volt, 3-phase electrical service. During the four demonstration sampling events the average and maximum energy usage for the overall system were 8.2 kW-hr and 12.6 kW-hr, respectively.

There were minimal storage space requirements for process chemicals. Process chemicals required for the demonstration included 50% methanol aqueous solution and a liquid chlorine solution. The methanol solution was stored in a 100-gallon plastic tank near the de-oxygenating and EcoMat reactors. The chlorine solution was stored in a 5-gallon pail beside the post- treatment system. Any reagents required for system monitoring (e.g., Nitrate-N, Nitrite-N, DO, pH, etc.) were stored in small Styrofoam shipping containers on shelving inside the shed. All process residuals (spent filters and biocarriers, clarifier sludge) were placed in plastic trash bags and stored in the shed until final disposal as domestic trash.

2.7 Limitations of the Technology

The EcoMat BDN technology is a treatment system designed to remove excess nitrate and, with appropriate post-treatment may also remove chlorinated hydrocarbons (e.g., CCl_4), methanol, and microorganisms. The maximum removal of nitrates was achieved during the demonstration when the flow through the system was in the 3.0 - 5.0 gpm range. At this flow rate it is obvious that the system would not be appropriate for supplying large residential communities with adequate supplies of treated water. The system may be more applicable to reducing or eliminating nitrate in small community water supplies, in industrial wastewaters, or in the leachate from commercial, industrial, or hazardous waste sites.

The growth of healthy microbial populations within each of the system's reactors is the key factor in determining the effectiveness of the technology. The growth of these organisms is dependant upon factors such as a sufficient source of carbon, a continuous low dissolved oxygen concentration (< 1.0 mg/l), an acceptable steady pH and temperature range, and intimate contact between the biocarrier and contaminated water. Also, like most biological systems, the system can be inhibited by toxics (e.g., heavy metals) in the source water. Many of these factors are dependent upon a system that has minimal operational/mechanical problems and system shutdowns.

During the course of the demonstration project, the EcoMat Biological Denitrification System, which is designed to operate unattended, had numerous operational/mechanical problems that required immediate attention from on-site demonstration staff. System shutdowns occurred on approximately seven occasions; two of which occurred due to electrical storms and five occurring from system mechanical problems. A number of other operational problems occurred, impacting effluent quality but not causing system shutdown.

The majority of operational/mechanical problems encountered during the demonstration were remedied quickly; normally within minutes to a couple hours of learning of the problem. However, during the second sampling event, a faulty compressor switch in the de-oxygenating tank caused a chain-reaction of other problems downstream of the tank, thereby forcing the demonstration team to abort the event.

It should be noted that the SITE team was not present during periods between the four events to monitor system perturbations (if they occurred). System shutdowns occurring during demonstration events that were not caused by an electrical storm are summarized below:

- Just prior to starting Event 2 (in July 1999) compressor switches in the de-oxygenating tank failed to monitor the water level in the tank. This prevented the switch from controlling the submersible pump delivering water from the well to the system. The malfunctioning switches were replaced with a "flapper" to control flow to the tank. This delayed the start of Event 2.
- Replacement of the compressor switch in the de-oxygenating tank required system shutdown and drainage of the tank. This maintenance activity caused the biocarrier to settle in the EcoMat reactor and clog the lower perforated screen used to separate the biocarrier mixing zone from the lower portion of the reactor. EcoMat drained the water level in the tank to allow pressure washing of the screen. The draining disrupted the microbe colonies and further delayed the start of Event 2.
- Activation of the high level alarm occurred on four separate occasions while no high levels were observed. The high level alarm shuts off the pump routing water to the EcoMat reactor. The shutdowns occurred twice during the aborted Event 2 in early July 1999, and twice again during Event 3 in October 1999.
- Towards the end of Event 3, a high level alarm was activated and the system was shut down due to excessive biological growth occurring on one of the post-treatment system filters. The filters were bypassed to complete the sampling event.

As stated earlier, other problems encountered during the demonstration affected the concentrations of parameters that are critical to treatment effectiveness and compliance with federal drinking water standards. These problems are summarized below.

- During Event 4 EcoMat discovered air entering the de-oxygenating reactor via the reactor feed pump. This increased the dissolved oxygen concentration in the reactor and disrupted the anoxic environment inhabited by the denitrifiers. EcoMat switched pumps to mitigate the problem.
- An ozone leak was found in the post-treatment system at the start of Event 3. This leak reduced the system's ability to oxidize residual nitrite to nitrate, oxidize residual methanol, and destroy bacteria. EcoMat replaced a leaking hose soon after the leak was discovered via gas detector tube monitoring.
- The pump feeding methanol either malfunctioned or was inadvertently turned off during Event 4. With no methanol being fed into the system, there was no carbon source for bacterial cell growth and nitrate consumption was reduced.

- Significant solids carryover from the BDN system to the post-treatment system caused unexpected frequent maintenance on the filters and clarifier. This occurred routinely during Event 2, when filters were first incorporated into the post-treatment system. Maintenance activities included replacing filters, back washing filters, and draining the clarifier. Also, large concentrations of heterotrophic bacteria and high turbidity readings in the system's final effluent made the water unacceptable for drinking purposes.
- High methanol concentrations (range: 14.6 - 98 mg/l) in the final effluent also made this water unacceptable for drinking purposes. These high methanol concentrations were caused by excessive feed rates, or by the failure of the post-treatment systems to oxidize residual methanol.

2.8 ARARS for the EcoMat BDN Technology

This subsection discusses specific federal environmental regulations pertinent to the operation of the EcoMat Biological Denitrification and Post-Treatment processes including the transport, treatment, storage, and disposal of wastes and treatment residuals. These regulations are reviewed with respect to the demonstration results. State and local regulatory requirements, which may be more stringent, must also be addressed by remedial managers. Applicable or relevant and appropriate requirements (ARARs) include the following: (1) the Comprehensive Environmental Response, Compensation, and Liability Act; (2) the Resource Conservation and Recovery Act; (3) the Clean Air Act; (4) the Clean Water Act; (5) the Safe Drinking Water Act, and (6) the Occupational Safety and Health Administration regulations. These six general ARARs are discussed below; specific ARARs that may be applicable to the EcoMat BDN and Post-Treatment Process are identified in **Table 2-1**.

2.8.1 *Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)*

The CERCLA of 1980 as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986 provides for federal funding to respond to releases or potential releases of any hazardous substance into the environment, as well as to releases of pollutants or contaminants that may present an imminent or significant danger to public health and welfare or to the environment. As part of the requirements of CERCLA, the EPA has prepared the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) for hazardous substance response. The NCP is codified in Title 40 Code of Federal Regulations (CFR) Part 300, and delineates the methods and criteria used to determine the appropriate extent of removal and cleanup for hazardous waste contamination.

SARA states a strong statutory preference for remedies that are highly reliable and provide long-term protection. It directs EPA to do the following:

- use remedial alternatives that permanently and significantly reduce the volume, toxicity, or the mobility of hazardous substances, pollutants, or contaminants;
- select remedial actions that protect human health and the environment, are cost-effective, and involve permanent solutions and alternative treatment or resource recovery technologies to the maximum extent possible; and
- avoid off-site transport and disposal of untreated hazardous substances or contaminated materials when practicable treatment technologies exist [Section 121(b)].

In general, two types of responses are possible under CERCLA: removal and remedial action. Superfund removal actions are conducted in response to an immediate threat caused by a release of a hazardous substance. Many removals involve small quantities of waste of immediate threat requiring quick action to alleviate the hazard. Remedial actions are governed by the SARA amendments to CERCLA. As stated above, these amendments promote remedies that permanently reduce the volume, toxicity, and mobility of hazardous substances or pollutants. The EcoMat BDN and post-treatment systems are likely to be part of a CERCLA remedial action since the toxicity of the contaminants of concern is reduced by either denitrification or oxidation. Remedial actions are governed by the SARA amendments to CERCLA. On-site remedial actions must comply with federal and more stringent state ARARs. ARARs are determined on a site-by-site basis and may be waived under six conditions: (1) the action is an interim measure, and the ARAR will be met at completion; (2) compliance with the ARAR would pose a greater risk to health and the environment than noncompliance; (3) it is technically impracticable to meet the ARAR; (4) the standard of performance of an ARAR can be met by an equivalent method; (5) a state ARAR has not been consistently applied elsewhere; and (6) ARAR compliance would not provide a balance between the protection achieved at a particular site and demands on the Superfund RPM for other sites. These waiver options apply only to Superfund actions taken on-site, and justification for the waiver must be clearly demonstrated.

Table 2-1. Federal and State ARARs for the EcoMat BDN Process.

Process Activity	ARAR	Description	Basis	Response
Characterization of untreated waste	RCRA: 40 CFR Part 261 (or state equivalent)	Standards that apply to identification and characterization of wastes.	Chemical and physical properties of waste determine its suitability for treatment by the EcoMat BDN Process.	Chemical and physical analyses must be performed to determine if waste is a hazardous waste.
Waste Processing	RCRA: 40 CFR Part 264 (or state equivalent)	Standards apply to treatment of wastes in a treatment facility.	Applicable or appropriate for the EcoMat BDN Process.	When hazardous wastes are treated, there are requirements for operations, record keeping, and contingency planning.
	CAA: 40 CFR Part 50 (or state equivalent)	Regulations govern toxic pollutants, visible emissions and particulate matter.	During process operations, any off-gases (i.e., from ozonation, air stripping, etc.) must not exceed limits set for the air district of operation. Standards for monitoring and record keeping apply.	Off-gases may contain volatile organic compounds or other regulated substances; although, levels are likely to be very low.
Storage of auxiliary wastes	RCRA: 40 CFR Part 264 Sub-part J (or state equivalent)	Regulation governs standards for tanks at treatment facilities.	Storage tanks for liquid wastes (e.g., decontamination waste) must be placarded appropriately, have secondary containment and be inspected daily.	If storing non-RCRA wastes, RCRA requirements may still be relevant and appropriate.
	RCRA: 40 CFR Part 264 Subpart I (or state equivalent)	Regulation covers storage of waste materials generated.	Potential hazardous wastes remaining after treatment (i.e., spent biocarrier, etc.) must be labeled as hazardous waste and stored in containers in good condition. Containers should be stored in a designated storage area and storage should not exceed 90 days unless a storage permit is obtained.	Applicable for RCRA wastes; relevant and appropriate for non-RCRA wastes.
Determination of cleanup standards	SARA: Section 121(d)(2)(ii); SDWA: 40 CFR Part 141	Standards that apply to surface & groundwater sources that may be used as drinking water.	Applicable and appropriate for the EcoMat BDN Process used in projects treating groundwater for use as drinking water.	Remedial actions of surface and groundwater are required to meet MCLGs or MCLs established under SDWA.
Waste disposal	RCRA: 40 CFR Part 262	Standards that pertain to generators of hazardous waste.	Waste generated by the EcoMat process which may be hazardous is limited to spent carbon, well purge water, spent media or biocarriers, clarification/filtration residual wastes, and decontamination wastes.	Generators must dispose of wastes at facilities that are permitted to handle the waste. Generators must obtain an EPA ID number prior to waste disposal.
	CWA: 40 CFR Parts 403 and/or 122 and 125	Standards for discharge of wastewater to a POTW or to a navigable waterway.	Applicable and appropriate for well purge water and decontamination wastewater generated from process.	Discharge of wastewater to a POTW must meet pre-treatment standards; discharges to a navigable waterway must be permitted under NPDES.

2.8.2 *Resource Conservation and Recovery Act (RCRA)*

RCRA, an amendment to the Solid Waste Disposal Act (SWDA), is the primary federal legislation governing hazardous waste activities. It was passed in 1976 to address the problem of how to safely dispose of the enormous volume of municipal and industrial solid waste generated annually. Subtitle C of RCRA contains requirements for generation, transport, treatment, storage, and disposal of hazardous waste, most of which are also applicable to CERCLA activities. The Hazardous and Solid Waste Amendments (HSWA) of 1984 greatly expanded the scope and requirements of RCRA. RCRA regulations define hazardous wastes and regulate their transport, treatment, storage, and disposal. These regulations are only applicable to the EcoMat Biological Denitrification and Post-Treatment processes if RCRA defined hazardous wastes are present.

Hazardous wastes that may be present include the aqueous waste to be treated, spent media or biocarriers from each of the reactors, and the residual wastes generated from any process included in the post-treatment system, such as clarification and filtration. If wastes are determined to be hazardous according to RCRA (either because of a characteristic or a listing carried by the waste), essentially all RCRA requirements regarding the management and disposal of this hazardous waste will need to be addressed by the remedial managers. Wastes defined as hazardous under RCRA include characteristic and listed wastes.

Criteria for identifying characteristic hazardous wastes are included in 40 CFR Part 261 Subpart C. Listed wastes from specific and nonspecific industrial sources, off-specification products, spill cleanups, and other industrial sources are itemized in 40 CFR Part 261 Subpart D. RCRA regulations do not apply to sites where RCRA-defined wastes are not present.

Unless they are specifically delisted through delisting procedures, hazardous wastes listed in 40 CFR Part 261 Subpart D currently remain listed wastes regardless of the treatment they may undergo and regardless of the final contamination levels in the resulting effluent streams and residues. This implies that even after remediation, treated wastes are still classified as hazardous wastes because the pre-treatment material was a listed waste.

For generation of any hazardous waste, the site responsible party must obtain an EPA identification number. Other applicable RCRA requirements may include a Uniform Hazardous Waste Manifest (if the waste is transported off-site), restrictions on placing the waste in land disposal units, time limits on accumulating waste, and permits for storing the waste.

Requirements for corrective action at RCRA-regulated facilities are provided in 40 CFR Part 264, Subpart F (promulgated) and Subpart S. These subparts also generally apply to remediation at Superfund sites. Subparts F and S include requirements for initiating and conducting RCRA corrective action, remediating groundwater, and ensuring that corrective actions comply with other environmental regulations. Subpart S also details conditions under which particular RCRA requirements may be waived for temporary treatment units operating at corrective action sites and provides information regarding requirements for modifying permits to adequately describe the subject treatment unit.

2.8.3 *Clean Air Act (CAA)*

The CAA establishes national primary and secondary ambient air quality standards for sulfur oxides, particulate matter, carbon monoxide, ozone, nitrogen dioxide, and lead. It also limits the emission of 189 listed hazardous pollutants such as vinyl chloride, arsenic, asbestos and benzene. States are responsible for enforcing the CAA. To assist in this, Air Quality Control Regions (AQCR) were established. Allowable emission limits are determined by the AQCR, or its sub-unit, the Air Quality Management District (AQMD). These emission limits are based on whether or not the region is currently within attainment for National Ambient Air Quality Standards (NAAQS).

The CAA requires that treatment, storage, and disposal facilities comply with primary and secondary ambient air quality standards. Emissions from post-treatment systems associated with EcoMat's Biological BDN may need to meet current air quality standards. For example, the ozonation system may be regulated by state or local agencies. Also, State air quality standards may require additional measures to prevent emissions, including requirements to obtain permits to install and operate processes (e.g., air strippers for control of VOCs).

2.8.4 *Clean Water Act (CWA)*

The objective of the Clean Water Act is to restore and maintain the chemical, physical and biological integrity of the nation's waters by establishing federal, state, and local discharge standards. If treated water is discharged to surface water bodies or Publicly Owned Treatment Works (POTW), CWA regulations will apply. A facility desiring to discharge water to a navigable waterway must apply for a permit under the National Pollutant Discharge Elimination System (NPDES). When a NPDES permit is issued, it includes waste discharge requirements. Discharges to POTWs also must comply with general pretreatment regulations outlined in 40 CFR Part 403, as well as other applicable state and local administrative and substantive requirements.

The demonstration did have a variety of available options for disposal of the water. These options included discharge 1) to a 1000 gallon septic system, 2) to a nearby down gradient drainage network, 3) back down PWS Well #, and 4) into the ground down gradient of PWS Well #1. After careful review, option #1 was selected as the most viable.

Treated effluent from the SITE demonstration was discharged to an on-site 1000 gallon septic system at a rate of approximately 7,200 gallons per day. Permission for septic system installation and discharge to the system was required by Doniphan County, KS. The county required the completion of a Sewage Facility Application/Permit. Approval for discharge to the septic system was granted by the KDHE.

The only listed option that would have been regulated under the CWA and required a NPDES permit would have been discharge to a nearby down gradient drainage network. It should be noted that depending on the levels of contaminants and permit limitations, additional treatment may be required prior to discharge.

2.8.5 *Safe Drinking Water Act (SDWA)*

The SDWA of 1974, as most recently amended by the Safe Drinking Water Amendments of 1986, requires the EPA to establish regulations to protect human health from contaminants in drinking water. The legislation authorized national drinking water standards and a joint federal-state system for ensuring compliance with these standards.

The National Primary Drinking Water Standards (NPDWS) are found in 40 CFR Parts 141 through 149. Parts 144 and 145 discuss requirements associated with the underground injection of contaminated water. If underground injection of wastewater is selected as a disposal means, approval from EPA or the delegated state for constructing and operating a new underground injection well is required.

Since the actual intent of the EcoMat BDN Process is to render the water as drinkable (i.e., reducing nitrate-N and nitrite-N to below their respective MCLs of 10 and 1 mg/l), in most cases treated effluent would be discharged directly into the community water system. For example, the treated effluent could be routed to 1) a water supply tank, 2) to an existing drinking water treatment system, or 3) a distribution system. If the final effluent of the system were to be used for drinking purposes while providing no additional treatment, the quality of the water would need to meet NPDWS.

During the demonstration elevated concentrations of both heterotrophic bacteria and methanol were found in the treated effluent. Heterotrophic bacteria, which are measured to determine how effective treatment is at controlling microorganisms, have no reported health effects. 40 CFR 141.72 of the NPDWS states that in lieu of measuring the residual disinfectant concentration in the distribution system, heterotrophic bacteria, as measured by the heterotrophic plate count, may be performed. If heterotrophic bacteria concentrations are found above 500/100 ml in the distribution system, the minimum residual disinfectant concentration is not in compliance with the NPDWS. There are no standards or health advisories for methanol in the NPDWS. The agency delegated for enforcement of the NPDWS would need to be notified of these elevated concentrations well before supplying this water to customers.

The NPDWS also have turbidity standards which must be met. A standard of 1.0 turbidity unit (NTU), as determined by a monthly average must be met. During the demonstration the calculated averages for three of the four sampling events were above the 1.0 NTU limit.

2.8.6 *Occupational Safety and Health Administration (OSHA) Requirements*

CERCLA remedial actions and RCRA corrective actions must be performed in accordance with the OSHA requirements detailed in 20 CFR Parts 1900 through 1926, especially Part 1910.120, which provides for the health and safety of workers at hazardous waste sites. On-site construction activities at Superfund or RCRA corrective action sites must be performed in accordance with Part 1926 of OSHA, which describes safety and health regulations for construction sites. State OSHA requirements, which may be significantly stricter than federal standards, must also be met.

If working at a hazardous waste site, all personnel involved with the construction and operation of the EcoMat BDN treatment process are required to have completed an OSHA training course and must be familiar with all OSHA requirements relevant to hazardous waste sites. Workers on hazardous waste sites must also be enrolled in a medical monitoring program. The elements of any acceptable program must include: (1) a health history, (2) an initial exam before hazardous waste work starts to establish fitness for duty and as a medical baseline, (3) periodic examinations (usually annual) to determine whether changes due to exposure may have occurred and to ensure continued fitness for the job, (4) appropriate medical examinations after a suspected or known overexposure, and (5) an examination at termination.

For most sites, minimum PPE for workers will include gloves, hard hats, steel-toe boots, and Tyvek® coveralls. Depending on contaminant types and concentrations, additional PPE may be required, including the use of air purifying respirators or supplied air. Noise levels are not expected to be high, except during well installation which will involve the operation of drilling equipment. During these activities, noise levels should be monitored to ensure that workers are not exposed to noise levels above a time-weighted average of 85 decibels over an eight-hour day. If noise levels increase above this limit, then workers will be required to wear hearing protection. The levels of noise anticipated are not expected to adversely affect the community, but this will depend on proximity to the treatment site.